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Issued August 26, 1915.

HAWAII AGRICULTURAL EXPERIMENT STATION,

J. M. WESTGATE, Agronomist in Charge.

Bulletin No. 40.

THE SOILS OF THE HAWAIIAN ISLANDS.

BY

W. P. KELLEY,
Chemist,

AND

WM. McGEORGE

AND

ALICE R. THOMPSON,
Assistant Chemists.

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HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of A. C. TRUE, Director of the States Relations Service, United States Department of Agriculture.]

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[1] Resigned October 27, 1914.

LETTER OF TRANSMITTAL.

HONOLULU, HAWAII, *September 29, 1914.*

SIR: I have the honor to submit herewith and recommend for publication as Bulletin No. 40 of the Hawaii Experiment Station a paper on The Soils of the Hawaiian Islands, by W. P. Kelley, chemist, and William McGeorge and Alice R. Thompson, assistant chemists. The soil investigations of the station for the past six years have greatly helped in elucidating Hawaiian soil problems. In the present bulletin the practical bearings of these scientific investigations are pointed out.

Respectfully,

E. V. WILCOX,
Special Agent in Charge.

Dr. A. C. TRUE,
Director, Office of Experiment Stations,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. TRUE, *Director.*

Publication authorized.
D. F. HOUSTON, *Secretary of Agriculture.*

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THE SOILS OF THE HAWAIIAN ISLANDS.

INTRODUCTION.

The purpose of this bulletin is to discuss briefly the general properties of the soils of the Hawaiian Islands and to point out the practical bearings of the investigations [1] that have been made on them. For about six years the writers have been investigating these soils. One phase of this work has been in the nature of a soil survey. In this connection a large number of samples have been collected and a number of unusual peculiarities and soil types have been observed. Soon after beginning this work it became apparent that the main body of Hawaiian soils had not been scientifically investigated. Considerable study had been previously devoted to the soils of Hawaii, but always with reference to special localities or industries. Maxwell's [2] discussion is based on analyses of samples drawn from the lands devoted to sugar cane and his use of the terms "uplands" and "lowlands" refers to the humid and arid, or upper and lower portions, respectively, of the sugar belt. However, only about 250,000 acres lying along the shore line, out of a total area of over 4,000,000 acres, are cultivated in this crop. The investigations upon which this bulletin is based were made principally on the upland soils above the sugar belt.

Almost the entire surface of Hawaii is characterized by a rolling topography. The elevation increases everywhere in passing inland from the sea, the grade varying in different localities. Each island contains one or more mountains or mountain ranges and usually with numerous spurs and sharp ridges projecting toward the sea. In almost every section the arable land is broken up by gulches or deep ravines, which now form natural watercourses, the beds of some of which have been worn to great depths. This has brought about the loss of a great amount of tillable land and adds greatly to the cost of farm operations. The tillable lands generally occur in comparatively narrow strips of irregular size and shape between gulches and extend from the sea toward the mountains.

It is difficult to estimate the area of arable land, only a small percentage of which has yet been brought under cultivation. The main portion is now being used for pasture in much the same way as in the great range sections of the mainland. The rainfall varies

[1] See Hawaii Sta. Buls. 26, 28, 30, 31, 33, 35, 37, and 38.

[2] Lavas and Soils of the Hawaiian Islands. Honolulu, 1898.

between wide extremes; in some localities semiarid or even arid conditions prevail, but over a large part of the uplands the rainfall is sufficient for a great variety of crops. In portions of the windward side of Maui and Hawaii, i. e., the side first reached by the northeast trade winds, the rainfall is very heavy. Until recently the main portion of the upland on account of its inadaptability to sugar was thought to be unsuited to cultivated crops. Slowly, however, it is being brought under cultivation and with the advent of a more numerous small farming class it is likely that practically all of the tillable lands of the islands will be utilized for cultivated crops. There are no valid reasons why general farming could not be practiced on these lands. The soils are rich and adapted to a wide range of crops. In the more arid sections the application of the principles of dry-land farming will doubtless insure the success of many crops. The increasing demands for land for cultivation in recent years have brought to the station many requests for information regarding the soils. A part of this information it is hoped will be supplied by this bulletin.

It should be understood from the outset that the methods of classification and mapping usually employed in soil surveys are not adapted to Hawaiian conditions and that nothing less than a systematic sampling of almost every acre will suffice to give an accurate idea of the location of all soil types. This is especially true of Oahu, where both the chemical and physical composition vary greatly in passing over short distances. For this reason no attempt to map the soil areas will be made. Furthermore, the peculiar properties of Hawaiian soils are such as to render the use of terms employed in the description of soil types elsewhere of doubtful application. In some instances the common systems of classification have been used, however, but the reader is cautioned against too strict interpretation of these terms.

The term "clay" especially requires definition. In the Tropics, where the soils have been formed from the disintegration of basaltic lava, the so-called clay is usually not composed of aluminum silicate, and its properties sometimes differ greatly from true clay. The soils of Hawaii, although usually very heavy in character and frequently containing as much as 50 per cent by weight of particles as fine as clay, are not clay soils in the true sense. They are characterized by a high content of iron and aluminum hydrates and low silica content. Such soils are designated as laterites, and recently the process leading to their formation has been designated as lateritization, in contradistinction to the term "kaolinization," used in reference to clay formation. The clay seems to be composed mainly of iron and aluminum hydrates and a double silicate of iron and alumina.

There are also some very unusual types of soil in the islands. On Oahu highly manganiferous and titaniferous soils occur, the former sometimes containing almost 10 per cent manganese oxid and the latter as high as 35 per cent titanium dioxid (TiO_2). No such soils are known to occur in any other country of the world.

ORIGIN AND FORMATION.

The soils of the Hawaiian Islands, with the exception of small areas near the sea, have been formed from the disintegration products of basaltic lava. The lava is composed mainly of pyroxenes, amphiboles, and soda-lime feldspars, with small amounts of magnetic oxid of iron. They are, therefore, highly ferruginous and basic. At the time of flow, and possibly to some extent afterwards, the vapors of burning sulphur act on the lava with the consequent formation of sulphates. The frequent occurrence of gypsum is traceable to this cause. The most important disintegrating agent is weathering. One of the first changes which takes place in the lava is that of oxidation. The iron in the original lava occurs mainly in the ferrous state, but upon exposure to the air the normal gray color quickly changes to red or yellow, due to the oxidation and subsequent hydration of the iron. Coincident with oxidation leaching takes place. The lime, magnesia, and soda to a large extent, and potash to lesser degree, are leached out by rain waters as silicates and carbonates, leaving behind a residue rich in iron and alumina, but much reduced in silica content.

The normal lavas from the main craters seem to be quite uniform in composition, while the flows from the secondary craters vary in composition, due perhaps to mixing with weathered and partially decomposed material near the surface. As oxidation proceeds, the surface of the lava crumbles away, thus allowing rain waters free access to the interior, and consequently greatly increasing the rate of solution. Another potent agent in the formation of soils is the growth and subsequent decay of plant roots. Within an incredibly short time after a lava flow plant life gains a foothold, which, aided by the solvent and oxidative effects naturally going on, soon pushes its roots into cracks and crevices. The carbonic acid given off by the roots aids in the decomposition, and the excessive heat of the tropical sun considerably hastens the solutions and oxidations going on. In general, soil formation is extremely rapid in the islands.

Much of the soil at the lower elevations has been formed by sedimentation and erosion from higher elevations. In fact there is much evidence that these processes account mainly for the location and formation of the sporadic types of manganiferous and titaniferous soils of Oahu. In many places, however, the soils are residual, with only slight transportation of soil material at most. In many sections

the disintegration has been so complete that scarcely a trace of unaltered lava can be detected in the soil.

The soils range from 6 inches to many feet in depth. After a few years of cultivation but little demarcation between the soil and the subsoil is left, except in locations of heavy rainfall. The humus content in passing downward decreases slowly, but the fertility in the drier sections is not greatly different for many feet below the surface. Where the drainage and aeration conditions are suitable, plant roots penetrate to great depths, and there is every indication that the plant food is as available several feet below as on the surface. No injurious effects, such as commonly follow the turning up of inert subsoil, are produced in the drier sections by plowing to the depth of 30 inches.

PHYSICAL PROPERTIES.

It is recognized that the physical properties of Hawaiian soils demand far more attention than usual; and it seems that purely physical factors within the control of the farmer are probably more important than the chemistry involved. The difficulties met with in the maintenance of suitable tilth, the rapidity with which the soil becomes closely compacted following rains, the lack of drainage and aeration, and the striking effects of green manuring and soil burning are all probably explainable in large part on physical grounds.

MECHANICAL CLASSIFICATION.

No attempt will be made to classify completely the soils of every section; in general, however, they may be divided into clay, silt, sandy, and humus soils. The clay type is the most abundant and in some instances contains unusually large amounts of clay, ranging as high as 50 per cent. The upland soils of Oahu, with the exception of the manganiferous and titaniferous areas, belong to the heavy clay type. The subsoils usually contain still more clay. In these sections practically no sand or gravel occurs, and the humus content is comparatively low. The soils of windward Oahu contain somewhat less clay than the above and more silt and gravel, and are consequently less difficult to till, but the subsoils contain higher percentages of clay and much less organic matter than the surface soils. The manganiferous and titaniferous soils, above referred to, are silty in character, while small areas of arable land in some localities around the coast on the leeward side of Oahu resemble adobe.

The Haiku district of Maui is composed largely of clay and clay loam soils with somewhat more humus than on Oahu. The Kula district is characterized by a light silty soil of high humus content which is several feet deep in some places. The Nahiku soils are high in humus and contain much stone and gravel. The soils of

west Maui, particularly the land of the Honolua Ranch Co., belong to the clay type.

On the island of Hawaii great diversity of soil types occur, and only the most general statements can be made at the present time. In the Olaa district, where the precipitation is very heavy, the soils contain a large amount of partially decomposed organic matter and are sandy or gravelly in texture. Along the Hamakua coast above the sugar belt a comparatively high percentage of clay occurs in some places; in others the soil has a high humus content. The soils of the Kohala district are clay loams, shading off to the west into silty loams. There is a large body of a deep, loose, silty soil, high in humus in this district that is now occupied by the Parker Ranch Co. In the Kona section the soils vary enormously. In places the virgin fern soils contain unusually high percentages of humus and, generally speaking, more or less stones and gravel.

The soils of Kauai, that have been most thoroughly investigated, were from Kapaa and the McBryde homesteads. The Kapaa lands contain high percentages of clay and are liberally supplied with humus; sometimes they resemble adobe. The McBryde homestead section is composed principally of clay loams. An insufficient number of samples have been examined from the other sections of the islands to justify any generalization. The table of mechanical analyses at the end of the bulletin will give some idea of the physical composition of representative samples from different districts.

DRAINAGE CONDITIONS.

Proper drainage is one of the greatest necessities in Hawaiian soil management. The rainfall in some sections is heavy throughout the year, and in almost all sections heavy rains sometimes occur. It is of the greatest importance that the excessive rains be able to drain away without eroding the surface into gullies or flowing over it, for in the latter event great injury will result from puddling the clay and shutting the air away from the roots of plants. Unless proper drainage be provided, suitable conditions of aeration in times of wet weather will be impossible. One of the most perplexing questions that the pineapple growers have had to contend with is that of drainage, and as yet no thoroughly satisfactory method has been devised. Generally the open-ditch system prevails. Drainage is naturally most difficult in heavy clay soils such as predominate in the pineapple sections.

The application of lime for the purpose of ameliorating the heavy clays seems to be of doubtful effect. In some instances lime fails to cause granulation such as takes place in normal clays. The clay is present in a state of such fine division as to be colloidal and has the power of imbibing large amounts of water. When wet the iron and

alumina become partially hydrated, and the soil mass swells considerably, thereby effectively closing the pores. Upon drying out contraction takes place, which results in the formation of large cracks. Thus the roots are injured and a condition provided for rapid evaporation of the soil moisture. This can be prevented only by increasing the humus and maintaining a mulch on the surface. It is evident from the above that a condition of insufficient aeration prevails in the clay soils during times of wet weather, and in fact anaerobic conditions often prevail.

Investigations on the physical properties of Hawaiian soils show that fertilizers exert considerable physical effect. Phosphates materially retard the movement of moisture in the heavy clays, while nitrate of soda produces similar effects in some of the highly organic soils. A number of fertilizing substances cause a deflocculation of the clay. It has been found, on the other hand, that heat causes the clay to become granulated and, therefore, is a means of increasing aeration and drainage.

The predominant color of Hawaiian soils is red, due to iron which is present in large amounts. Various shades of red often occur close together. There are also considerable areas of yellow soil. These colors seem to be referable to the state of hydration of the iron. The dark red color which predominates in the more arid sections is probably due to amorphous hematite and the yellow color to limonite. In the humid sections, where the humus content is not high, the color of the soil is generally lighter, due to the iron being in the ferrous form. The iron is generally so abundant and completely disseminated in the soil as to obscure the humus unless present in large amounts.

CHEMICAL CHARACTERISTICS.

Soils naturally partake to a considerable extent of the nature of the minerals from which they have been derived, and, since Hawaiian soils have been formed from basaltic lava, they are potentially basic. This does not mean, however, that in all cases the soils are free from acidity, as will be pointed out later. In general Hawaiian soils contain unusually high percentages of iron and alumina, the former sometimes exceeding 50 per cent by weight. The silica content is low as compared with mainland soils. Lime and magnesia are present in quite variable amounts, but usually more abundantly than in nonlimestone countries.

POTASH.

The potash content on the whole is rather below the average, but frequently it is relatively more soluble than usual and consequently more available. It is also more constant in different sections of the islands than any other of the so-called plant-food constituents.

PHOSPHORIC ACID.

Phosphoric acid is comparatively abundant, but there is a wide range of variation in the percentages present. The upland soils of Oahu generally, but not always, contain less phosphoric acid than any other extensive body of arable land in the islands. The soils of windward Oahu, with the exception of the lowlands devoted to rice, also usually contain small percentages of phosphoric acid. The Kula soils are rich in phosphoric acid, the Haiku soils intermediate, while in the Nahiku section of Maui the content is variable. The soils of Kohala on Hawaii are unusually rich in phosphoric acid. It must not be understood that the above statements apply universally to a given section for there is often great variation in comparatively short distances.

Notwithstanding the high percentages of phosphoric acid in many Hawaiian soils the availability is, on the whole, rather low, and phosphate fertilization is necessary in most instances except where the humus content is high. The low availability of the phosphoric acid is probably due to its being chemically combined with iron and aluminum in difficultly soluble combinations. Hawaiian soils have the power of fixing enormous amounts of soluble phosphates. Experiments have demonstrated that the red clay type of soil can fix more than 4 per cent of its weight of phosphoric acid. There is, therefore, very little danger of loss of phosphoric acid by leaching. On the other hand, it is also necessary to thoroughly mix phosphate fertilizers with the soil in order that the distribution of roots may not be too near the surface. Experiments seem to indicate that various phosphates continue to be available for a considerable time after having been applied, notwithstanding the fact that the phosphoric acid is insoluble in water. Decaying organic matter exercises a very marked effect on the availability of phosphates, and even insoluble forms may be made available by plowing under green manure.

NITROGEN.

As stated above, the humus content is high as compared with mainland soils, and consequently the nitrogen is also high, but its availability is low, due to poor aeration. The soils of Kula, Nahiku, Olaa, and parts of Kohala and Kona on Hawaii are generally very rich in nitrogen. Table II shows the percentages of humus and nitrogen in representative samples from these districts.

On account of there being a high percentage of nitrogen present, it is desirable to increase its availability whenever possible. This can best be done by increasing the aeration, thereby improving the conditions for bacterial action which decomposes the organic nitrogen into available forms. It has been found, however, that heating soil

greatly increases the ammonia content and is a means of making available a considerable portion of the nitrogen, but it should be remembered that in so doing considerable loss of nitrogen takes place through the destructive effect of the heat.

PECULIAR SOILS.

One of the peculiarities of Hawaiian soils is the unusually high content of some of the rarer elements, notably manganese and titanium, which are supposed not to be necessary for plant growth. The manganiferous soils, with relatively unimportant exceptions, are located only on Oahu between the Koolau and Waianae Mountains, but it is not possible to give an accurate estimate of the extent of this type or to trace its location in detail. In general, it may be said to occur most abundantly toward the lower levels between the mountain ranges, in pockets or level stretches that receive the drainage and wash from higher levels. This type of soil occurs most abundantly in the Waipio, Wahiawa, and Halemanu districts, but may also be found in portions of Waialua, Waimea, and in the upper part of the Oahu Sugar Co.'s land. There are also small areas of highly manganiferous soil near Haiku on Maui, Homestead on Kauai, and in the Palawai Basin of Lanai.

Sometimes the manganese areas are small, while in other places as much as 20 or more acres may occur in one body. The percentage of manganese varies greatly. A few tenths of 1 per cent occur in nearly all Hawaiian soils. The manganiferous soils, however, often contain more than 5 per cent, expressed as manganese oxid (Mn_3O_4). These soils are characterized by a dark color, sometimes almost black, due to the presence of manganese dioxid, and have a silty texture in contrast to the heavy clay character of the surrounding soils. Generally concretions composed of manganese dioxid can be found mixed with the soil and more abundantly in the subsoil. The manganese is nearly always more abundant in the soil than in the subsoil. In some places where the surface soil contains more than 4 per cent the subsoil contains less than 1 per cent. A high manganese content is quite injurious to pineapples, causing the leaves to become yellow and lowering the quality of the fruit. Some other crops are also injuriously affected, but sugar cane, sisal, cabbage, turnips, and some other crops seem to be unaffected.

As in the case of the manganiferous soils, it is not possible to locate definitely all of the highly titaniferous areas. All Hawaiian soils contain comparatively high percentages of titanium. The soils of the Kunia section, however, are unusually high in titanium, containing in some instances as much as 35 per cent titanium dioxid (TiO_2), but the titanium is relatively insoluble, and consequently the usual agricultural analysis fails to show the total amount present.

It seems that titanium is inert toward plant growth. It is extremely insoluble and occurs to some extent as small fragments of a black mineral, possibly ilmenite. Generally speaking, the titanium soils are silty, but sometimes they have a very fine texture. In a few places in the upper portion of the Wahiawa district, Opaeula and Kunia on Oahu, and near Pogue's station on Maui it occurs in the form of a blue gray layer composed of very fine particles which soil the fingers very much like charcoal. Sometimes a high percentage of ferrous iron is associated with the titanium. If phosphoric acid should become chemically combined with the titanium, the insoluble nature of this compound would render it unavailable to plants.

CORAL SAND SOILS.

These soils are of relatively small importance and are located near the sea level. Such soils, as the name indicates, have been formed mainly from grains of coral sand, which are composed chiefly of calcium carbonate. After the sand banks have been built up above sea level, organic matter and small amounts of soil gradually become incorporated with them, and certain plants soon gain a foothold, resulting in the formation of humus and later in a fairly fertile soil. An important use to which the coral beds and sand banks are being put is as a source of lime which is recommended for use where liming is needed.

LIME-MAGNESIA RATIO.

Hawaiian lava contains considerably more lime than magnesia, but frequently the opposite is the case with the soil. Generally speaking, the soils formed from black sand contain much higher percentages of magnesia than lime. Therefore, the lime-magnesia ratio is abnormal. So far as is now known, however, no injurious effects are produced on crops. Experiments carried out with the object of modifying the ratio of lime to magnesia have not indicated any practical advantage to be derived in this way. The lime is much more soluble than the magnesia, even where the magnesia content greatly exceeds that of lime.

ACIDITY OF HAWAIIAN SOILS.

Notwithstanding the highly basic character of Hawaiian soils, they generally give an acid reaction toward litmus. The acidity, as determined by the Vietch method, sometimes indicates the need of large amounts of lime. In harmony with this is the very low content of carbonate except where coral sand is present. The soils around Honolulu, for example, contain not more than 0.1 per cent carbon dioxid (CO_2), although the lime and magnesia are high. It has been supposed that the sod lands are generally acid, but it seems that the slow growth of crops is due more to the lack of aeration than the presence of actual acidity. Lime has been used to considerable

extent on the sugar lands with good effects, but in many instances negative results have been obtained by the pineapple growers. Where liming is to be practiced, coral sand is recommended.

With the exception of phosphoric acid, all the mineral elements of plant food in Hawaiian soils are soluble in water to a considerable extent, and if suitable physical conditions be maintained, and the humus content kept up, the need for mineral fertilizers will be greatly reduced. The solubility of the mineral constituents can also be considerably increased by soil heating, which probably is a factor in the more vigorous growth of crops noticed where refuse had been burned.

FERROUS IRON.

Soluble ferrous iron is considered to be toxic to plants, but the amount of water soluble ferrous iron in Hawaiian soils is extremely small, except where there is insufficient aeration. Poor drainage and an excess of water in soils prevents the circulation of air, and such conditions are favorable for the formation of soluble ferrous iron. The injurious effects on crops attending heavy rains may be due to some extent to the formation of ferrous compounds. The high iron content of Hawaiian soils is composed in part of insoluble ferrous oxid, but the imperfections in analytical methods do not permit of its accurate determination. Consequently the percentages of ferrous iron are not given in the tables of analysis.

BIOLOGICAL CONDITIONS.

The availability of nitrogen in soils depends on the activity of bacteria and fungi. There are many factors that influence their activity, one of the most important of which is the state of aeration. In general the aeration of Hawaiian soils is not sufficient for the best development of beneficial bacteria. Consequently the nitrogen does not become available fast enough for maximum growth of crops.

NITRIFICATION.

Nitrification in soils requires the free movement of air, and the more restricted the circulation of air the less actively are nitrates formed. This is strikingly illustrated by contrasting nitrification in the silty soils of Kula and the Parker ranch, where active nitrification takes place, with that of the heavy clay types common in other parts of the islands. In the rice soils nitrification is suspended and the clay soils frequently contain almost no nitrate. The inertness often observed in newly plowed sod lands is due in part to the lack of nitrification. It follows, then, that any treatment which increases soil aeration also stimulates nitrification. As pointed out above, aeration may be increased by increasing the humus content, and probably one of the most important reasons for the beneficial

effects of green manuring is that it stimulates bacterial action. It is commonly believed that the presence of carbonate of lime is essential for nitrification, through the maintenance of neutral conditions, but it seems that when other conditions are suitable, active nitrification takes place in Hawaiian soils which contain unusually small amounts of lime. The results of our experiments indicate that the iron and alumina present may partially take the place of lime in maintaining the necessary neutral condition. On the other hand, experiments show that magnesium carbonate seems to be distinctly detrimental to nitrification, while the magnesia naturally present in the soils does not seem to interfere. While nitrate is probably the most available form of nitrogen, ammonia is also available for certain crops.

AMMONIFICATION.

Ammonification is more active in Hawaiian soils than nitrification, and investigations show that aeration is not as essential to this process as it is to nitrification. Aeration, however, also stimulates ammonification. During the several months, in which new lands are usually cultivated previous to planting, ammonification and nitrification are each stimulated to a considerable extent, but in many localities only very small amounts of nitrate are found. In such instances plants seem to absorb the nitrogen most largely in the form of ammonia. In the case of aquatic plants ammonia is preferable to nitrates. Soil heating stimulates the formation of ammonia, both as a direct result of the heat on the organic nitrogen and probably indirectly, by increasing the activity of bacteria. It has also been found that the application of lime stimulates the formation of ammonia, and magnesium carbonate produces still greater stimulation. The effects of magnesium carbonate on ammonification are therefore the opposite of those on nitrification.

All Hawaiian soils seem to be abundantly supplied with bacteria, and the wide distribution and vigorous growth of a great variety of leguminous plants indicate that the tubercle-forming organisms are abundantly distributed. In fact, nodules occur on the roots of many leguminous plants in the islands. Up to the present time very little use has been made of artificial inoculation, and it is of doubtful importance.

SOIL MANAGEMENT.

TILLAGE.

A part of the high cost of tillage in Hawaii is traceable to the unusual properties of the soil. The clay when wet is extremely sticky and, even when the moisture content is low, it adheres tenaciously to the plow, thus materially increasing the draft. Frequent deep

plowing, however, is a necessity. The subsoil, upon standing, becomes closely compacted, and heavy rains and walking over the surface greatly increase this tendency. Consequently it is necessary to replow at frequent intervals. In many localities the aeration is restricted to a layer a few inches in depth near the surface and nitrification scarcely ever becomes active. Deep plowing will permit the absorption of a much larger percentage of heavy rains, thus greatly reducing erosion and storing up much larger amounts of moisture for drier seasons. Most of the soils that are cultivated in pineapples become hard and closely compacted within a few months after planting. Consequently it is necessary to plow as deeply as possible between crops.

Subsoiling has not been extensively practiced, but deep plowing should be the rule in all sections. The subsoils are not very different from the soils, except in some of the rainy sections like Olaa, and, after being acted upon for a short time by weathering influences, seem to be equally as fertile as the surface soil. In the drier sections deep plowing encourages deeper root development, thus tending to enable the crop to withstand drought. Successful soil management in Hawaii, therefore, requires deep plowing, followed by frequent shallow cultivation.

INJURIOUS EFFECT OF PUDDLING.

Great care and intelligence must always be exercised in plowing and tilling clay soils. The clay particles are extremely small and tend to settle down between the coarser grains, thus clogging the pores. However, the fine particles can be made to unite into granules by the judicious handling of the soil. In the natural state carbonic acid formed from the decomposition of vegetation and aided by evaporation causes the smaller particles to coalesce into granules, which then act as if the particles themselves were coarse. In this condition a heavy clay soil may be well aerated and fertile. On the other hand, tillage, in times of too great moisture, breaks up the granules, producing a puddled condition which is very difficult to bring back into a state of granulation.

During the early stages of the cultivation of sod lands the bacterial processes bring about a rapid decomposition of the vegetable matter, which causes the clay to become granulated. After a few years, however, the organic matter has been so completely decomposed that the clay is easily puddled under the ordinary operations of cultivation. A single cultivation of such soils when they are wet causes serious puddling. The pineapple growers in the Wahiawa district have greatly injured their lands by cultivating too soon after rains. Much of the so-called exhaustion of Hawaiian pineapple soils is traceable to wet cultivation.

ROTATION OF CROPS.

The rotation of crops is essential to a permanent upkeep of the soil. It is not necessary to enumerate the reasons for this fact. Some of them still remain in obscurity. Crop rotation is of very great importance in the proper management of Hawaiian clay soils. As stated above, the humus is considerably above the average, but the peculiarities of the clay necessitate still greater amounts. The fine particles of iron and alumina become hydrated when wet and adhere to all the soil particles. Only by the maintenance of large amounts of humus can such soils be kept in a suitable condition for plant growth.

The pineapple growers, following the lead of the sugar planters, have attempted to grow the same crop continuously, but in many cases with poor results. The reason is found in the need for humus. Crop rotation will supply this need, if a green manuring crop be plowed under. Humus is the key to successful soil management in Hawaii as is the case elsewhere. At the present time this fact is being recognized by the sugar planters as never before. Instead of burning the trash and crop residue, they should be plowed under, thereby increasing the humus content. Organic matter undergoes rapid decomposition in the Tropics, and the necessary condition of aeration hastens the decomposition. It is necessary, therefore, to plow under green manure frequently. The details of crop rotation will not be discussed in this bulletin. With the pineapple lands a green manuring crop can be grown between crops. The choice of the green manuring crop will depend on the locality. It should be a legume if possible. The single-crop system can not be permanent, and it is of doubtful economy at any time. Sooner or later it must inevitably give way to diversification.

The retention of moisture during dry weather can be greatly increased by increasing the humus content of the soil, so that sufficient moisture will be retained for the growth of crops during continued dry weather. The success of crops in the semiarid sections of Kula and the Parker ranch is due very largely to the high humus content of the soils. On one of the fields at the experiment station, where a legume has been plowed under each year for the past several years, the structure of the soil has been materially modified and the moisture-retaining power greatly increased. Similar effects can be had with any of the clay soils throughout the islands. Hawaiian clay soils require a higher percentage of moisture than is usual, due to their high hygroscopic capacity and the slow movement of moisture through the soil. Hygroscopic moisture will not sustain plant life.

EROSION AND DRAINAGE.

The amount and extent of soil erosion in Hawaii can hardly be overestimated. The heavy rains wash away enormous quantities of soil. This can be prevented by a combination of deep plowing, proper drainage, and green manuring. When the soil is compacted rain waters flow over the surface rather than being absorbed, thus washing away much soil material and cutting gullies. Where ditches are provided they should be arranged close together in the direction of the greatest fall, so as to carry away the surplus water and prevent overflow. In some places much damage has been done to crops by the overflow from inadequate ditches. The use of dynamite, for the purpose of shattering the subsoil and allowing better drainage, has been practiced with good results in some localities. The plowing under of coral sand has also been effectively used in some localities as a means of improving aeration and drainage conditions, and around Honolulu gardeners frequently mix black sand with the soil for the same purpose.

USE OF FERTILIZERS.

The table of chemical analyses at the end of the bulletin shows that, on the whole, Hawaiian soils are well supplied with phosphoric acid and nitrogen with a medium content of potash. In many localities the soil contains unusually high percentages of phosphoric acid and nitrogen. Nevertheless, heavy fertilization is generally practiced, due to the low availability of plant food. It is more rational, however, to make available the plant food already contained in the soil, if this can be done economically. The methods by which this may be accomplished have already been suggested. These consist briefly in increasing the aeration by deep plowing, thorough drainage, and the frequent plowing under of green manures, which, if carried out systematically, will materially lessen the need for commercial fertilizers.

The exact fertilizer for each crop varies in different districts. In general both nitrogen and phosphoric acid give good results. Nitrate of soda, ammonium sulphate, and organic forms of nitrogen each produce good effects, but, generally speaking, organic forms and ammonium sulphate are recommended in preference to nitrate of soda, especially during seasons of heavy rainfall. The soils have the power of absorbing large amounts of ammonium sulphate, thus preventing its being leached out, but nitrate of soda is not fixed by soils.

When the organic matter is deficient the phosphoric acid is generally of low availability and phosphate fertilizers are needed. Soluble phosphates will give best immediate returns, but if applied in conjunction with decaying organic matter, insoluble forms may be used. Pot experiments at the station, carried through several crops, indi-

cate that rock phosphate, when acted upon for a few months by decaying organic matter, becomes as available as superphosphate, but when applied without organic matter the immediate effect is negligible. From these experiments it also seems that water-soluble phosphates produce better immediate effects than reverted phosphate and bone meal. It has also been found that the availability of the phosphate already in the soil can be considerably increased by plowing under green manure, and that liming in some instances is necessary before phosphate fertilizer will give its best effects. Hawaiian soils have the power of fixing very large amounts of phosphoric acid, and, therefore, loss will not be sustained by leaching. It seems, however, that where excessive amounts have been applied some of the phosphoric acid becomes reverted into unavailable forms.

When potash fertilizer is needed the sulphate is recommended, and potash, like ammonia, is not lost by leaching if applied in reasonable amounts.

CHEMICAL AND MECHANICAL COMPOSITION OF SOME HAWAIIAN SOILS.

In the following tables are given the results of chemical and mechanical analyses of a large number of soils and subsoils taken from different parts of all of the principal islands. In Table I the results of the chemical analyses of soils and subsoils[1] are given; in Table II the humus, humus ash, and total nitrogen are stated; and in Table III the mechanical composition is shown. In general the soil represents the first foot and the subsoil the second foot taken. In most instances the material analyzed represents a composite of from two to five samples taken in the same locality. The methods employed for the chemical analysis were those of the official agricultural chemists. The classification of soils adopted in the table of mechanical composition is that of Hall.[2]

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[1] The subsoil in all cases was taken in connection with the preceding soil sample.

[2] The Soil. London, 1908, 2. ed., p. 51.

TABLE I.—*Chemical composition of Hawaiian soils.*

Soil No.	Location.	Color.	Water (H_2O).	Volatile matter.	Insoluble residue.	Ferric oxid (Fe_2O_3).	Alumina (Al_2O_3).	Titanium dioxid (TiO_2).	Manganese oxid (Mn_3O_4).	Lime (CaO).	Magnesia (MgO).	Potash (K_2O).	Soda (Na_2O).	Phosphoric acid (P_2O_5).	Sulphur trioxid (SO_3).	Nitrogen (N).
	HAWAII.															
	Kohala district.															
	Puuanahulu:		*Per ct.*	*Per ct.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per ct.*
326	1,300-foot level	Brown	10.72	13.93	35.21	12.75	19.82	3.40	0.56	0.66	0.73	0.41	0.37	1.24	0.22	0.33
327	1,400-foot level	do	13.10	14.24	32.48	12.52	20.00	2.60	.96	.46	.89	.42	.22	1.26	.49	.26
328	1,500-foot level	Red	4.91	24.55	31.83	11.49	22.03	2.70	.94	.70	.71	.39	.32	.46	.21	.27
	Parker ranch, Waimea:															
474	Soil	Brown	13.59	20.01	33.77	7.00	16.79	1.80	.07	3.80	.85	.72	.10	2.18	.45	.65
475	Subsoil	do	16.08	20.25	30.10	8.68	17.20	2.00	.02	3.58	1.02	.40	.22	1.34	.50	.60
470	Soil	do	12.66	19.81	38.05	8.36	11.02	1.60	.20	5.41	1.16	.47	.14	2.32	.44	.68
471	Subsoil	Yellow	20.69	14.33	36.44	8.76	12.30	2.20	.13	3.00	1.49	.40	.13	.45	.37	.38
	Parker ranch, Makahalau:															
468	Soil	Brown	11.52	18.92	44.06	8.80	8.93	2.00	.14	2.32	1.42	.22	.33	.86	.36	.64
469	Subsoil	Black	11.00	29.14	18.44	13.72	17.78	4.03	.19	3.11	1.26	.19	.37	.63	.43	.54
74	Parker ranch, Waikii	Brown	25.46	13.08	32.69	10.13	12.59	.....	.13	2.63	1.09	.14	.34	1.02	.22	.44
75	Do	do	[1]38.45	11.82	27.44	7.52	11.27	.....	.03	1.77	1.07	.15	.32	.22	.20	.23
76	Do	do	[1]33.85	11.79	32.17	8.36	11.25	.....	.02	1.54	.87	.13	.28	.17	.18	.18
	Hamakua district.															
	Paauhau:															
472	Soil	Brown	[1]28.88	25.11	13.75	16.04	10.93	4.00	.10	.39	.52	.16	.18	.25	.32	.53
473	Subsoil	do	[1]40.64	21.88	9.24	10.84	12.62	3.20	.08	.32	.46	.18	.15	.20	.37	.27
134	Kukaiau ranch	do	15.01	23.80	24.93	18.41	14.14	.....	.24	.72	1.54	.82	.47	.61	.27	.77
	Hilo district.															
448	Hilo Boarding School	Yellow	16.00	25.58	15.10	19.20	16.64	4.20	.06	.50	1.80	.15	.68	.29	.53	.49
	Olaa district.															
	Glenwood:															
216	Soil	Black	9.28	23.38	38.13	12.46	10.33	.....	.03	3.37	2.10	.18	.60	.23	.41	.73
217	Subsoil	do	13.51	25.46	24.63	16.06	15.27	.....	.02	1.35	1.67	.10	.48	.17	1.28	.51
218	Soil	do	11.33	23.57	35.58	11.94	11.62	.....	.22	2.20	2.36	.14	.41	.24	.39	.59
219	Do	do	9.46	24.61	37.84	18.56	4.23	.....	.28	2.15	1.78	.28	.36	.25	.39	.74
220	Subsoil	do	14.49	26.10	22.24	17.04	16.31	.....	.11	1.19	1.90	.27	.15	.18	.47	.56
221	Soil	do	7.85	21.16	41.89	13.64	8.89	.....	.23	2.89	2.43	.33	.49	.21	.29	.55
428	Do	do	14.94	22.24	34.99	8.24	10.73	3.20	.20	1.91	2.24	.24	1.40	.45	.22	.74
459	Do	do	[1]25.30	18.25	29.50	9.24	8.95	2.00	.11	2.26	2.71	.14	.23	.29	.25	.51

	Kau district.															
	Pahala, 3,000-foot level:															
497	Soil	Brown	4.83	12.24	47.39	7.28	11.73	3.80	.43	6.34	5.82	.58	1.58	.27	.52	.36
498	Subsoil	do	16.95	15.89	32.41	7.40	17.62	5.00	.36	.84	2.58	.22	.68	.17	.74	.24
	Hawaii Agricultural Co. plantation:															
499	Soil	Black	7.20	15.50	46.14	6.35	10.96	3.60	.20	4.54	4.32	.42	1.02	.40	.58	.52
500	Subsoil	Brown	15.68	16.90	32.07	7.52	18.93	5.80	.16	.66	2.22	.22	.74	.27	.46	.28
	Pahala:															
531	Soil	Yellow	9.63	14.05	39.55	13.92	16.93	.....	.14	1.84	2.92	.18	.36	.36	.38	.....
532	Subsoil	do	10.18	11.13	41.61	13.76	17.13	.....	.19	1.84	3.66	.18	.24	.27	.42	.....
533	Soil	Brown	7.33	14.00	45.16	13.76	11.88	.....	.18	2.60	3.90	.24	.58	.29	.38	.....
534	Subsoil	do	5.72	8.58	48.90	13.48	12.49	.....	.19	5.02	4.70	.24	.92	.40	.38	.....
535	Soil	Yellow	10.60	17.67	34.06	14.80	18.63	.....	.18	1.44	2.38	.24	.50	.43	.34	.....
536	Subsoil	do	12.23	13.79	33.84	16.56	19.09	.....	.25	1.62	2.64	.12	.32	.38	.32	.....
	Kona district.															
112	Keauhou, Hawaii Tobacco Co.	Brown	21.85	25.48	18.21	16.08	16.82	.....	.12	.45	.84	.10	.09	.29	.41	.55
113	Do	do	16.30	28.16	21.32	16.73	13.91	.....	.06	.72	.99	.14	.11	.41	.49	.28
	Honaunau:															
422	460-foot level	Black	10.71	36.50	26.43	7.44	7.76	1.40	.17	5.74	1.86	.23	.51	.96	.43	1.68
423	Subsoil	do	9.69	22.29	35.92	9.64	11.83	1.80	.18	5.80	2.23	.18	.54	.77	.48	.81
420	Lot 67, 510-foot level.	Brown	12.27	19.35	34.23	11.36	14.85	1.80	.26	2.78	2.03	.22	.28	.74	.37	.59
421	Subsoil	do	15.01	14.53	34.28	11.20	17.95	3.00	.21	2.36	1.48	.17	.23	.47	.27	.29
424	Lot 77, 680-foot level.	Black	10.34	18.69	40.86	9.32	12.85	1.80	.33	3.14	1.73	.27	.40	.55	.90	.69
425	Subsoil	do	10.50	14.70	43.02	10.08	13.77	2.20	.25	3.03	1.61	.18	.43	.59	.30	.46
418	Lot 36, 760-foot level.	do	9.87	14.36	45.48	9.00	14.19	1.98	.14	2.31	1.45	.29	.29	.97	.30	.41
419	Subsoil	do	9.43	12.26	47.09	9.84	13.97	2.00	.15	2.49	1.55	.23	.20	.98	.30	.31
	Kiilae:															
437	2,050-foot level	do	16.86	56.51	13.17	5.56	3.10	1.00	.52	2.46	.85	.15	.19	.40	.49	2.13
438	Subsoil	do	22.30	31.36	20.38	4.40	13.42	7.20	.08	.36	.53	.11	.15	.13	.30	.61
439	2,760-foot level	do	25.82	34.55	11.33	11.64	12.20	3.40	.08	.59	.63	.08	.19	.24	.33	.74
440	Do	do	[1] 42.11	29.58	13.14	4.88	6.26	3.20	.34	.80	.63	.16	.21	.20	.26	.92
	KAUAI.															
	Kona district.															
	Kekaha:															
495	Soil	Red	5.97	14.40	37.84	14.08	19.52	4.20	.24	1.60	1.16	.52	.38	.55	.34	.01
496	Subsoil	do	6.15	11.89	41.92	14.16	19.54	4.00	.20	.62	1.12	.50	.52	.36	.46	.01
	Makaweli:															
493	Soil	do	4.43	15.69	34.59	16.32	22.71	3.60	.26	.82	.64	.50	.40	.51	.46	.28
494	Subsoil	do	7.39	12.39	38.92	16.64	18.58	3.60	.16	.52	.76	.48	.42	.47	.50	.09
210	Soil	do	3.63	9.51	37.12	30.78	15.84	.....	.39	.78	.51	.26	.47	.41	.30	.16

[1] Not completely air-dried.

TABLE I.—*Chemical composition of Hawaiian soils*—Continued.

Soil No.	Location.	Color.	Water (H_2O).	Volatile matter.	Insoluble residue.	Ferric oxid (Fe_2O_3).	Alumina (Al_2O_3).	Titanium dioxid (TiO_2).	Manganese oxid (Mn_3O_4).	Lime (CaO).	Magnesia (MgO).	Potash (K_2O).	Soda (Na_2O).	Phosphoric acid (P_2O_5).	Sulphur trioxid (SO_3).	Nitrogen (N).
	KAUAI—continued.															
	Kona district—Con.		*Per ct.*	*Per ct.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per ct.*
120	Hanapepe	Brown	5.52	16.84	27.19	24.07	24.06	0.25	0.43	0.05	0.32	0.37	0.22	0.47	0.30	0.25
119	Do	do	5.55	12.96	32.59	29.11	17.32	.50	.10	.05	.73	.51	.12	.25	.21	.25
118	Do	do	6.10	14.71	21.15	33.00	22.23	.40	.17	.05	.45	.39	.32	.26	.23	.23
117	Do	Red	6.24	18.65	17.96	32.05	22.17	.20	.12	.06	.57	.31	.48	.45	.25	.23
116	Do	do	7.25	17.41	16.50	35.32	21.28	.30	.17	.10	.34	.20	.45	.39	.22	.28
	Homestead, Kukuiolona:															
433	Soil	Brown	8.81	20.62	28.81	11.96	23.32	.60	4.14	.73	.66	.40	.46	.59	.35	.46
434	Subsoil	Red	5.24	14.23	35.29	14.72	25.54	.60	2.81	.45	.58	.18	.19	.24	.23	.12
	Kauai Fruit & Land Co.:															
209	Soil	do	6.86	24.05	25.76	32.46	15.58	.....	.05	.40	.74	.16	.20	.84	.39	.25
429	Do	Brown	9.96	17.84	25.96	21.76	20.37	2.80	.08	.23	.65	.23	.30	.24	.35	.30
430	Subsoil	Red	8.61	14.91	26.41	23.92	23.40	1.60	.10	.24	.52	.22	.19	.18	.25	.16
	McBryde homestead, 1,000-foot level:															
431	Soil	do	10.30	17.30	27.51	19.84	21.06	2.40	.10	.27	.70	.13	.21	.18	.34	.27
432	Subsoil	do	8.86	13.82	32.71	17.04	24.79	1.40	.04	.27	.72	.18	.18	.33	.18	.11
207	Homestead	do	5.88	16.50	34.17	20.60	20.03	.....	.18	.43	.49	.44	.20	1.01	.39	.36
	Koloa:															
373	Soil	Brown	8.77	19.58	26.08	20.04	21.96	1.20	.09	.26	.73	.42	.22	.66	.36	.29
374	Subsoil	Red	7.53	15.19	28.65	22.64	22.77	1.20	.04	.16	.54	.40	.37	.55	.31	.13
375	Soil	Brown	8.82	21.81	17.80	24.16	22.47	1.40	.01	.49	.77	.30	.29	1.05	.38	.38
376	Subsoil	Red	8.53	17.04	19.33	26.56	25.59	1.20	.02	.20	.49	.31	.33	.81	.27	.13
	Puna district.															
208	Nawiliwili, coral soil.	Gray	.95	20.28	2.82	2.28	.11	.....	.00	68.64	2.59	.27	.05	.48	.53	.12
	Kapaa:															
200	Soil	Brown	23.78		30.84	42.43		.....	.14	.32	.68	.50	.74	.13	.44	.36
426	Do	do	10.47	18.28	24.80	22.52	19.10	3.80	.22	.15	.44	.28	.74	.19	.39	.29
427	Subsoil	Yellow	12.80	17.10	16.62	28.92	21.93	1.60	.11	.30	.59	.25	.40	.29	.34	.16
	Koolau district.															
212	Anahola	Red	16.66	10.10	37.84	19.02	24.31	.....	1.39	.93	.60	.44	.29	.49	.49	.37
211	Kilauea plantation	do	9.50	18.52	19.97	36.28	13.77	.....	.06	.29	.45	.26	.30	.83	.38	.31

	Halelea district.															
460	Hanalei	Brown	13.71	12.15	36.56	14.04	17.31	2.40	.08	1.08	2.31	.14	.09	.38	.23	.22
461	Do	do	13.24	12.43	35.10	14.84	17.46	2.60	1.01	.84	2.91	.23	.09	.45	.24	.21
462	Do	do	10.23	11.03	42.47	13.32	17.15	2.40	.02	1.07	2.06	.17	.36	.48	.31	.18
463	Do	do	11.29	9.25	41.72	16.16	12.07	1.80	.04	.86	6.20	.15	.30	.31	.27	.16
464	Do	do	11.83	11.45	39.83	13.56	17.92	2.60	.12	1.12	1.52	.13	.37	.45	.25	.18
465	Do	do	11.83	10.05	40.37	13.44	17.66	2.00	.20	1.18	2.34	.12	.40	.64	.28	.13
466	Do	do	14.50	10.12	38.81	15.56	14.53	2.20	.13	.80	3.53	.13	.25	.27	.23	.15
467	Do	do	10.89	11.88	38.51	14.20	18.09	2.40	.12	1.04	2.71	.15	.30	.50	.28	.15
	LANAI.															
121	Beet-sugar soil	Red	5.41	17.58	33.44	18.93	19.99	.20	1.13	1.15	.45	.41	.39	.43	.26	.33
	Komoku:															
412	Soil	do	5.88	18.64	29.26	20.00	21.13	2.40	.75	1.07	.67	.49	.22	.52	.39	.52
413	Do	do	5.10	14.28	27.96	29.20	16.33	4.20	.40	.87	.61	.33	.11	.15	.33	.44
414	Subsoil	do	5.00	11.44	29.68	30.88	18.40	3.20	.05	.54	.44	.25	.22	.16	.25	.20
	MAUI.															
	Hamakuapoko district.															
	Haiku:															
60	Soil	Brown	2.98	10.14	34.93	36.88	12.56	.....	.07	.15	1.25	.25	.18	.20	.23	.27
62	Do	do	4.42	16.10	34.16	21.66	21.17	.....	.83	.24	.83	.48	.13	.17	.38	.30
174	Soil, 1-2 inch depth	Slate	.62	3.60	40.12	47.04	.12	3.80	.16	.54	2.12	.34	.53	.11	.72	.07
175	Subsoil, 30-inch depth.	do	2.38	6.54	38.50	44.75	.12	3.80	.22	.46	1.68	.32	.53	.11	.74	.12
321	Maui cannery, Haiku.	Brown	4.47	13.48	32.90	30.59	13.17	3.80	.05	.44	.95	.27	.11	.30	.35	.27
322	Do	do	4.53	13.74	25.24	34.00	16.98	3.80	.04	.33	.88	.15	.06	.56	.32	.17
323	Do	do	3.59	10.03	33.96	35.05	12.24	3.40	.04	.26	.81	.14	.10	.28	.25	.16
324	Do	do	16.48	.....	27.29	31.62	15.78	5.00	.04	.15	.61	.....	.....	.45	.25	.20
325	Do	do	6.80	5.67	30.74	36.86	11.34	6.60	.14	.14	.80	.15	.23	.66	.12	.11
542	Baldwin pineapple land, Haiku.	do	5.50	13.96	30.54	19.44	13.15	5.40	.17	.21	.99	.20	.15	.52	.19	.27
543	Do	do	5.53	14.62	29.28	19.44	23.27	5.20	.20	.20	.97	.17	.13	.64	.09	.31
544	Do	Yellow	4.33	13.62	28.65	25.28	21.53	5.00	.16	.09	.94	.22	.18	.19	.11	.26
545	Do	Brown	5.45	16.34	27.03	20.32	24.51	4.20	.46	.11	.91	.28	.10	.22	.22	.32
546	Do	do	4.34	13.87	33.35	26.72	15.78	5.20	.08	.12	1.09	.23	.05	.26	.10	.28
547	Do	do	3.12	12.20	34.54	23.80	17.72	6.20	.08	.40	1.25	.19	.13	.43	.10	.26
548	Do	do	3.88	9.29	37.60	30.60	10.46	5.40	.10	.25	1.31	.11	.25	.36	.16	.19
549	Do	do	3.50	9.94	32.50	33.00	10.16	7.20	.17	.13	1.41	.17	.28	.28	.16	.23
550	Do	do	4.04	11.50	32.19	32.00	11.07	6.00	.13	.23	1.23	.20	.28	.38	.12	.27
551	Do	do	4.21	9.84	35.03	29.16	12.53	7.60	.35	.33	1.30	.27	.22	.48	.13	.28
552	Do	Red	4.27	12.74	28.82	36.53	11.16	5.20	.10	.09	.82	.28	.22	.19	.11	.27
554	Lilikoi	do	4.98	12.62	32.63	32.32	9.87	5.20	.02	.23	.84	.19	.31	.35	.14	.31
555	Do	do	4.45	12.82	31.98	32.16	11.64	5.00	.03	.43	1.02	.17	.15	.30	.28	.40
556	Do	do	5.72	16.00	25.74	32.60	13.24	5.00	.15	.24	.68	.16	.11	.22	.22	.24
557	Do	do	4.52	14.79	26.20	32.00	14.82	4.80	.05	.27	.88	.23	.10	.29	.24	.34
558	Do	Brown	5.41	14.70	26.20	26.32	19.23	5.20	.06	.33	.85	.39	.12	.38	.25	.30

TABLE I.—*Chemical composition of Hawaiian soils*—Continued.

Soil No.	Location.	Color.	Water (H_2O).	Volatile matter.	Insoluble residue.	Ferric oxid (Fe_2O_3).	Alumina (Al_2O_3).	Titanium dioxid (TiO_2).	Manganese oxid (Mn_3O_4).	Lime (CaO).	Magnesia (MgO).	Potash (K_2O).	Soda (Na_2O).	Phosphoric acid (P_2O_5).	Sulphur trioxid (SO_3).	Nitrogen (N).
	MAUI—continued.															
	Hamakuapoko district—Continued.															
			Per ct.	*Per ct.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per ct.*
559	Lilikoi	Brown	6.27	17.91	22.97	27.92	17.50	5.20	0.39	0.31	1.14	0.26	0.06	0.32	0.17	0.30
560	Do	do	4.20	12.63	31.44	33.48	10.15	5.60	.13	.27	.79	.23	.17	.32	.12	.30
561	Do	do	4.67	14.00	28.98	29.84	15.46	4.60	.11	.39	.88	.23	.26	.34	.31	.31
562	Do	do	4.59	14.65	28.68	33.16	11.65	5.20	.22	.29	.95	.23	.30	.49	.21	.38
563	Do	do	4.36	15.77	25.90	30.56	14.95	5.60	.17	.20	.74	.28	.28	.48	.25	.31
564	Do	do	5.18	13.26	30.88	31.40	11.25	5.40	.11	.14	.87	.24	.27	.38	.20	.32
565	Do	do	4.60	12.74	31.28	28.20	15.68	4.80	.13	.09	.84	.30	.23	.33	.24	.27
	Koolau district.															
69	Nahiku	Brown	12.57	39.86	18.48	15.40	10.95	.....	.09	.86	1.16	.18	.32	.22	.56	1.32
202	Do	do	19.96	17.56	22.45	17.22	18.96	.....	.08	.87	2.16	.14	.25	.52	.42	.37
203	Do	do	19.12	25.10	17.88	18.48	17.29	.....	.10	.32	.79	.24	.30	.55	.67	.66
204	Do	do	13.44	18.02	21.98	33.48	11.51	.....	.06	.21	.76	.21	.19	.29	.47	.24
205	Do	do	16.44	19.02	17.98	18.56	22.70	.....	.01	.81	2.94	.20	.26	.40	.75	.24
206	Do	do	16.27	22.58	29.78	19.74	9.03	.....	.08	.45	.81	.19	.16	.45	.67	.65
370	Koolau forest	Gray	5.04	23.58	49.38	8.68	8.87	3.60	.02	.29	1.04	.39	.43	.05	.23	.58
371	Do	do	3.04	10.34	73.01	6.76	3.29	2.40	.02	.29	.74	.49	.33	.05	.21	.35
	Kaupo district.															
	Catholic Church:															
523	Soil	Brown	9.26	24.99	30.45	15.24	11.78	.....	.17	2.92	3.44	.88	.24	.73	.80	.....
524	Subsoil	do	10.52	22.21	28.52	16.52	14.27	.....	.23	2.62	3.12	.56	.52	.71	.88	.....
	Omsted place:															
525	Soil	do	9.40	19.87	27.12	20.04	19.65	.....	.13	.72	1.00	.44	.46	.75	.78	.....
526	Subsoil	do	9.73	17.19	29.63	20.04	20.18	.....	.15	.70	1.04	.58	.58	.70	.70	.....
527	Soil	do	9.68	20.66	27.47	24.52	15.02	.....	.04	.46	.90	.56	.32	.40	1.00	.....
528	Subsoil	do	10.82	19.16	26.90	24.24	16.32	.....	.10	.18	.74	.80	.04	.26	.80	.....
529	Popoiki	do	9.24	23.00	30.90	16.52	.....	.....	.43	1.94	2.32	.70	.58	.97	.84	.....
	Kula district.															
	Alexander field:															
105	Soil	Brown	4.81	11.32	35.19	31.68	15.40	.....	.12	.07	.84	.23	.19	.36	.29	.27
109	Subsoil	do	11.38	13.49	25.56	26.86	20.98	.....	.14	.08	.35	.28	.12	.54	.82	.09
106	Soil	do	5.17	11.78	31.63	33.43	15.79	.....	.17	.11	.85	.21	.15	.50	.21	.25
108	Subsoil	do	8.86	15.10	22.93	27.74	22.95	.....	.14	.06	.63	.25	.17	.79	.75	.11

	Dowdle field:															
107	Soil	...do	3.82	9.51	34.52	36.56	13.65	.....	.23	.05	.88	.16	.07	.36	.22	.22
110	Subsoil	...do	11.12	12.95	25.58	32.01	16.36	.....	.23	.09	.50	.21	.13	.78	.32	.12
	Ulupalokua:															
377	Soil	...do	12.33	13.69	32.73	12.88	17.17	2.40	.20	3.30	2.65	.38	.57	.71	.26	.31
378	Subsoil	...do	15.29	14.21	30.40	13.68	17.05	2.60	.29	2.69	3.38	.28	.66	.67	.25	.27
	Cromwell ranch:															
379	Soil	...do	12.64	25.30	18.88	13.76	23.44	3.20	.34	.90	1.10	.20	.36	.73	.33	.52
380	Subsoil	...do	18.18	22.71	16.58	13.76	23.26	3.60	.17	.55	.97	.17	.37	.65	.28	.35
	Kamaole Church:															
381	Soil	...do	11.29	20.40	26.39	14.24	19.57	3.00	.24	1.87	1.82	.25	.37	.55	.30	.49
382	Subsoil	...do	13.73	17.45	30.30	12.52	18.36	2.60	.30	2.59	1.73	.19	.46	.49	.31	.38
	Kamaole.															
383	Soil	Black	10.26	31.17	28.42	9.52	10.73	1.60	.84	4.44	2.03	.28	.70	.81	.50	1.29
384	Subsoil	...do	12.89	32.14	24.47	10.20	11.62	1.40	.47	4.57	1.83	.22	.51	.70	.62	1.38
	Waiakoa store:															
385	Soil	...do	9.56	19.03	27.02	13.96	21.06	3.40	.41	2.46	1.82	.34	.45	.74	.38	.45
386	Subsoil	Brown	10.71	19.86	26.80	13.88	21.63	3.20	1.48	2.55	1.84	.41	.45	.79	.32	.45
	Ulupalakua:															
387	Soil	Black	2.14	7.11	43.77	11.08	14.39	2.20	.28	9.80	5.78	1.03	2.38	.48	.32	.22
	Kaanapali district.															
	Honolua:															
361	450-foot level	Red	10.03	12.72	40.05	14.56	18.34	1.80	.72	.54	.59	.34	.31	.40	.53	.30
362	Subsoil	...do	10.19	10.30	41.07	12.88	22.32	1.60	.24	.44	.46	.31	.27	.32	.46	.12
363	650-foot level	Brown	8.35	13.26	38.61	15.36	20.10	2.40	.59	.46	.72	.23	.25	.32	.49	.29
364	Subsoil	...do	8.20	12.07	39.63	15.64	21.31	2.00	.34	.32	.52	.22	.25	.27	.36	.14
365	850-foot level	Red	8.79	14.02	32.80	27.08	11.76	4.00	.32	.30	.59	.23	.24	.26	.38	.36
366	Subsoil	...do	10.82	14.35	26.66	25.96	17.77	3.20	.04	.30	.39	.20	.23	.31	.43	.15
	MOLOKAI.															
	Pukoo district.															
91	Soil	Red	7.68	12.10	.....	18.83	22.29	.....	.20	.46	.71	.....	.....	.37	.20	.15
92	Subsoil	...do	8.18	11.98	.....	17.29	24.64	.....	.18	.25	.80	.....	.....	.33	.14	.14
93	Soil	Brown	5.91	13.92	.....	19.97	26.64	.....	.21	.20	.69	.....	.....	.46	.18	.16
94	Subsoil	...do	6.06	14.33	.....	20.85	25.01	.....	.04	.16	.76	.....	.....	.43	.21	.14
95	Soil	Red	11.53	18.38	.....	20.34	19.46	.....	.27	.24	.76	.....	.....	.32	.20	.22
	Molokai ranch.															
222	Near ranch house	Red	4.18	12.56	38.56	21.12	20.93	.....	.57	.69	.50	.46	.16	.51	.26	.....
	Naiwa district.															
	1,500-foot level:															
349	Soil	Red	4.39	9.90	38.73	32.36	8.61	4.60	.11	.34	.87	.23	.20	.37	.15	.24
350	Subsoil	...do	8.68	13.56	26.81	34.86	11.73	2.80	.02	.20	.52	.31	.23	.46	.16	.19

TABLE I.—*Chemical composition of Hawaiian soils*—Continued.

Soil No.	Location.	Color.	Water (H_2O).	Volatile matter.	Insoluble residue.	Ferric oxid (Fe_2O_3).	Alumina (Al_2O_3).	Titanium dioxid (TiO_2).	Manganese oxid (Mn_3O_4).	Lime (CaO).	Magnesia (MgO).	Potash (K_2O).	Soda (Na_2O).	Phosphoric acid (P_2O_5).	Sulphur trioxid (SO_3).	Nitrogen (N).
	MOLOKAI—continued.															
	Naiwa district—Con.															
	1,050-foot level:		*Per ct.*	*Per ct.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per ct.*
351	Soil	Red	3.94	7.94	30.65	38.16	11.31	5.00	0.02	0.41	0.76	0.39	0.40	0.87	0.28	0.20
352	Subsoil	do	6.63	11.21	28.64	31.90	16.21	3.70	.02	.28	.56	.39	.50	.62	.09	.18
	860-foot level:															
353	Soil	do	6.18	12.84	34.67	15.64	26.15	2.40	.09	.41	.94	.29	.30	.59	.05	.18
354	Subsoil	do	5.67	12.34	36.42	15.20	24.87	3.20	.38	.58	.70	.31	.28	.69	.33	.13
	600-foot level:															
355	Soil	do	4.80	12.17	37.75	17.92	23.10	2.20	.90	.54	.56	.30	.26	.38	.40	.12
356	Subsoil	do	5.24	11.50	37.27	17.25	23.90	2.40	.74	.45	.58	.34	.35	.47	.36	.10
	380-foot level:															
357	Soil	do	4.36	12.12	38.60	15.56	24.51	3.00	.14	.28	.42	.15	.26	.40	.29	.08
358	Subsoil	do	8.63	7.16	39.76	13.32	28.14	2.40	.05	.21	.52	.20	.43	.30	.31	.08
	30-foot level:															
359	Soil	do	5.74	13.12	38.87	15.36	21.46	2.80	.16	.59	.84	.22	.23	.37	.49	.25
360	Subsoil	do	6.15	13.75	40.49	13.76	21.38	2.00	.20	.88	1.01	.29	.52	.62	.34	.19
	OAHU.															
	Kona district.															
	Waikiki:															
71	Soil	Brown	8.75	5.76	37.21	19.60	13.60	.....	.36	2.19	12.06	.48	.82	.66	.19	.16
292	Do	do	7.65	8.42	38.49	16.63	12.85	2.00	.24	1.84	8.71	.39	1.36	.57	.08	.12
293	Subsoil	do	12.72	8.67	33.88	18.56	11.39	2.31	.18	2.17	8.51	.41	1.19	.62	.10	.14
122	Experiment station	do	7.36	11.55	35.37	35.40		.....	.42	.82	6.24	1.32	.72	.35	1.30	.21
251	Experiment station, field B 1.	Red	9.66	10.08	32.41	26.80	14.01	.....	.26	1.22	4.23	1.30	.12	.68	.25	.15
	Experiment station, field B 2:															
288	Soil	do	8.29	12.10	36.87	15.90	13.42	2.22	.44	1.10	7.94	.97	.76	.34	.08	.21
289	Subsoil	do	10.36	11.70	36.96	15.12	15.20	1.92	.23	.80	5.86	.66	.50	.28	.07	.15
	Experiment station, field D:															
290	Soil	Black	8.44	15.80	40.02	16.41	14.11	1.50	.30	.77	1.30	.17	.42	.27	.10	.19
291	Subsoil	do	9.33	12.77	41.21	15.89	15.39	1.25	.18	.67	1.41	.17	.40	.20	.09	.13

	Kalihi:															
332	Soil	Brown	11.39	12.38	39.56	16.66	15.13	2.00	.28	.86	.83	.22	.41	.28	.03	.16
333	Subsoil	do	12.65	11.81	40.05	16.14	15.21	1.90	.26	.76	.51	.23	.31	.23	.09	.13
334	Soil	do	8.81	12.53	41.00	16.03	17.82	1.40	.12	.74	.90	.25	.31	.41	.21	.21
405	Do	do	8.02	12.50	39.12	15.24	20.54	2.40	.15	.86	.99	.20	.48	.44	.33	.20
406	Do	do	10.34	17.73	37.31	10.92	20.20	1.80	.06	.48	.67	.20	.48	.48	.30	.41
408	Experiment station, Tantalus.	Black	11.35	18.28	22.72	19.24	17.29	3.60	.14	.42	4.94	.34	.18	1.13	.28	.45
537	Alewa heights	do	9.70	13.48	39.24	21.16	14.95	.....	.28	.66	1.10	.22	.40	.21	.40	.....
	Ewa district.															
63	Puuloa, Honolulu plantation.	Brown	11.07	10.34	38.14	12.04	21.63	2.20	.32	.54	2.58	.32	.46	.35	.38	.....
64	Do	do	10.36	10.62	36.62	16.32	19.55	2.30	.44	.52	2.24	.34	.58	.42	.30	.....
68	Do	do	10.41	10.54	36.42	17.76	18.70	2.20	.62	.50	2.22	.48	.98	.37	.28	.....
	Waipio district.															
213	Robinson	Red	5.51	14.31	36.44	18.16	22.71	.....	.19	.69	.55	.30	.43	.42	.42	.28
46	Do	do	7.20	19.18	30.75	16.00	22.05	.....	3.05	.62	.36	.58	.24	.21	.76	.44
	Pearl City Fruit Co.:															
27	Soil	Black	14.74	11.95	35.88	18.80	13.65	.....	3.53	.16	.29	.55	.27	.11	.31	.22
28	Subsoil	do	15.74	9.95	36.04	18.00	16.44	.....	3.02	.18	.23	.55	.31	.09	.26	.16
29	Soil	Red	14.26	13.17	37.76	16.40	15.83	.....	1.13	.28	.22	.55	.28	.10	.39	.25
30	Subsoil	do	15.12	9.99	38.93	17.12	17.09	.....	.43	.14	.38	.62	.20	.06	.23	.17
31	Soil	do	16.70	14.35	34.75	19.40	13.34	.....	.19	.19	.30	.44	.17	.07	.38	.24
32	Subsoil	do	21.25	12.88	29.34	19.00	16.42	.....	.31	.12	.23	.45	.29	.09	.26	.16
114	Hawaiian Pineapple Co.	do	5.15	15.75	40.66	14.99	19.71	.03	2.40	.10	.47	.45	.22	.24	.23	.30
416	Do	do	6.17	17.73	36.09	13.20	20.39	1.60	3.84	.33	.44	.39	.59	.20	.35	.36
417	Do	do	16.26	17.53	30.92	11.24	19.38	1.40	2.85	.21	.36	.45	.36	.24	.43	.38
435	Makua	do	4.31	12.89	39.72	16.08	22.68	2.40	.38	.40	.57	.55	.26	.34	.24	.16
436	Do	do	5.39	14.38	35.40	16.20	25.13	2.40	.14	.54	.56	.22	.24	.19	.23	.21
	Wahiawa district.															
	Hawaiian Pineapple Co.:															
5	Soil	Red	3.80	13.20	42.13	25.12	10.41	3.40	.26	.44	.39	.60	.19	.12	.08	.24
6	Subsoil	do	4.13	13.55	37.26	31.20	10.01	2.57	.18	.44	.34	.70	.28	.15	.02	.21
7	Soil	do	3.98	13.65	39.26	34.30	3.43	3.68	.21	.50	.36	.49	.20	.06	.08	.32
8	Subsoil	do	4.44	13.37	37.50	31.80	8.28	2.62	.05	.63	.36	.57	.30	.07	.06	.24
9	Soil	Black	5.36	16.78	31.67	18.60	14.67	.68	9.21	1.32	.52	.79	.38	.20	.15	.18
10	Subsoil	do	4.73	13.77	34.35	20.50	15.00	1.04	8.35	.82	.41	.70	.40	.15	.08	.22
11	Soil	do	4.59	18.81	37.23	17.40	14.69	3.90	4.58	.61	.39	.74	.34	.35	.22	.44
12	Subsoil	do	3.53	13.24	41.10	19.80	16.27	.56	3.38	.58	.37	.78	.42	.12	.04	.18
	Waikakalaua:															
13	Soil	Red	3.99	15.34	44.66	23.40	8.79	2.12	.32	.31	.39	.48	.30	.08	.10	.37
14	Subsoil	do	2.43	12.85	45.24	23.80	11.73	2.00	.34	.30	.43	.55	.12	.12	.11	.24

TABLE I.—*Chemical composition of Hawaiian soils*—Continued.

Soil No.	Location.	Color.	Water (H_2O).	Volatile matter.	Insoluble residue.	Ferric oxid (Fe_2O_3).	Alumina (Al_2O_3).	Titanium dioxid (TiO_2).	Manganese oxid (Mn_3O_4).	Lime (CaO).	Magnesia (MgO).	Potash (K_2O).	Soda (Na_2O).	Phosphoric acid (P_2O_5).	Sulphur trioxid (SO_3).	Nitrogen (N).
	OAHU—continued.															
	Wahiawa district—Continued.															
	Hawaiian Pineapple Co.:		*Per ct.*	*Per ct.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per ct.*
96	Soil	Red	12.25	15.33	.....	18.21	22.58	.....	0.47	0.24	0.56	.....	.....	0.11	0.14	0.28
97	Do	do	7.53	13.22	41.99	19.27	16.86	.....	.15	.30	.30	0.49	0.12	.17	.16	.23
98	Do	do	6.72	12.19	43.45	19.80	16.35	.....	.11	.57	.22	.48	.16	.17	.14	.23
99	Do	do	11.39	13.32	30.75	27.50	16.75	.....	.14	.09	.28	.44	.25	.14	.21	.24
101	Do	do	9.04	11.85	36.94	25.64	15.43	.....	.09	.15	.25	.36	.19	.18	.17	.22
102	Do	do	7.33	13.62	37.01	27.10	13.71	.....	.20	.11	.40	.42	.35	.18	.22	.25
103	Do	do	10.21	13.70	32.51	23.53	18.27	.....	.11	.04	.21	.35	.37	.09	.18	.21
104	Do	do	7.87	11.13	39.03	21.74	20.03	.....	.14	.05	.21	.42	.15	.14	.19	.19
100	Subsoil	do	13.58	13.38	25.02	23.10	23.76	.....	.12	.18	.13	.26	.43	.21	.17	.17
19	Thomas Pineapple Co.	do	8.03	12.82	40.46	25.70	10.95	0.26	.14	.22	.39	.54	.27	.02	.10	.26
21	Do	do	10.43	16.00	35.03	22.40	13.21	.21	.82	.26	.31	.68	.30	.08	.15	.30
	Hawaiian Preserving Co.:															
15	Soil	Black	7.82	15.38	31.15	24.00	14.58	.19	3.70	.46	.48	.91	.19	.32	.15	.32
16	Subsoil	do	9.16	11.75	31.37	24.40	17.24	1.44	2.21	.34	.38	.97	.35	.19	.04	.18
17	Soil	do	8.33	14.97	31.96	24.20	13.61	1.42	3.58	.34	.38	.97	.27	.16	.12	.28
517	Do	Red	3.54	13.71	41.99	21.76	17.23	.....	.12	.36	.32	.54	.23	.13	.58	.....
518	Subsoil	do	3.97	13.56	41.53	21.48	18.21	.....	.04	.20	.24	.66	.46	.16	.52	.....
130	Kunia	do	7.95	16.22	30.76	20.50	21.02	.....	1.18	.39	.55	.34	.23	.57	.37	.30
133	Mountain gap, Leilehua.	Gray	1.49	4.09	43.39	42.96	2.95	4.00	.03	.26	.66	.42	1.34	.09	.36	.05
72	Do	do	.82	1.34	65.90	26.75	2.24	2.16	.05	.12	1.00	.30	.96	.05	.52	.....
388	Government land, Leilehua.	Red	5.53	18.07	27.04	21.24	22.63	2.60	1.28	1.19	.51	.36	.14	.32	.35	.42
389	Do	do	2.86	18.43	29.51	22.76	20.71	2.80	1.24	.47	.53	.38	.09	.37	.29	.40
390	Do	do	6.39	14.18	31.09	23.20	19.40	3.60	.73	.47	.56	.32	.14	.18	.27	.36
391	Do	do	7.10	18.12	30.52	13.28	26.25	1.40	.48	.61	.47	.44	.18	.24	.27	.34
392	Do	do	5.51	19.00	29.64	15.72	24.78	1.80	2.26	.52	.50	.40	.21	.28	.31	.35
393	Do	do	9.01	18.35	28.57	11.60	26.01	1.20	4.04	.50	.53	.46	.15	.32	.24	.36
394	Do	do	3.17	7.72	26.82	39.00	13.29	9.00	.06	.33	1.01	.15	.03	.04	.19	.20
395	Do	do	3.01	5.42	37.80	35.80	9.73	6.60	.06	.73	.86	.15	.14	.17	.15	.15
396	Water tank, Leilehua.	Black	5.08	8.47	35.39	33.64	10.04	5.20	.01	.40	.59	.15	.06	.41	.20	.22
397	Dowsett House	Red	7.47	13.40	30.72	19.32	21.76	3.00	1.86	.35	.59	.37	.15	.59	.26	.20
398	Leilehua tract	Brown	6.89	18.88	29.22	15.16	19.55	2.20	6.42	.42	.61	.37	.14	.36	.30	.42
399	Do	Red	5.33	13.03	37.19	20.68	18.40	4.00	.04	.61	.63	.27	.18	.22	.25	.26

	Waialua district.															
140	Mokuleia	Brown	6.84	14.88	35.67	17.67	22.51	.....	.39	.52	.41	.42	.27	.87	.15	.31
141	Do	do	8.39	12.74	39.32	17.16	20.15	.....	.33	.42	.56	.41	.20	.56	.10	.41
142	Do	do	7.21	13.48	43.25	14.18	18.09	.....	.27	1.38	1.52	.52	.39	.32	.08	.36
143	Do	do	7.29	11.45	45.78	14.33	17.88	.....	.25	1.22	1.54	.20	.29	.15	.03	.27
331	Helemano	Red	7.49	18.69	35.21	14.84	18.20	1.40	3.26	.58	.48	.59	.05	.24	.70	.40
115	Do	do	5.66	12.17	38.22	27.89	13.86	.50	.10	.05	.80	.34	.32	.14	.17	.31
145	Opaeula Ridge	do	8.06	12.49	39.38	26.10	11.91	.....	.06	.36	1.12	.32	.43	.17	.52	.31
148	Do	do	12.50	10.81	35.62	26.37	13.33	.....	.07	.26	.74	.38	.13	.27	.54	.17
149	Do	do	16.66	10.45	34.50	27.30	9.79	.....	.07	.24	.80	.38	.11	.19	.68	.21
152	Do	do	14.04	15.28	29.73	14.84	20.73	.....	2.89	.26	.64	.42	.30	.29	.58	.32
155	Do	do	12.07	13.78	33.57	28.74	11.18	.....	.10	.18	.58	.36	.30	.25	.58	.24
164	Do	Gray	1.22	3.56	48.17	37.47	3.05	1.72	.10	.12	1.22	.48	1.46	.08	.44	.....
165	Do	do	.25	3.02	50.96	37.97	2.73	2.10	.06	.30	1.54	.42	1.46	.04	.34	.10
178	Waimea Ridge	Red	14.21	14.50	.....	14.58	17.35	.....	3.00	.50	.66	.45	.24	.43	.76	.36
186	Do	do	6.90	13.23	.....	20.86	17.30	.....	2.24	.74	.68	.40	.24	.16	.74	.....
187	Do	do	5.58	11.52	.....	33.16	11.55	.....	.10	.08	.52	.37	.24	.15	.80	.....
	Pupukea:															
49	Soil	do	15.51	11.49	35.79	17.20	17.21	.....	.99	.20	.39	.55	.38	.08	.20	.23
50	Subsoil	do	16.04	11.19	33.43	21.72	16.31	.....	.30	.10	.37	.40	.17	.08	.35	.11
51	Soil	Black	16.20	12.81	32.20	17.10	16.36	.....	3.62	.20	.53	.69	.28	.09	.24	.20
52	Subsoil	do	14.90	10.59	33.82	21.60	13.73	.....	3.61	.22	.42	.65	.39	.12	.24	.11
489	Pupukea, sea level	Red	5.30	14.72	36.81	18.48	21.96	2.20	.10	.48	.65	.40	.12	.31	.33	.27
490	Do	do	5.42	14.10	34.95	18.76	22.15	2.20	.34	.78	.72	.27	.16	.37	.34	.23
	Koolauloa district.															
	Koluanui:															
347	Soil	Black	9.07	31.48	34.46	6.42	13.10	2.08	.29	2.00	.72	.11	.28	.17	.30	1.13
348	Subsoil	do	13.16	40.53	24.10	5.60	10.80	1.65	.30	2.40	.68	.08	.28	.11	.70	1.25
	Koolaupoko district.															
	Waiahole:															
345	Soil	do	8.76	12.13	46.11	15.76	13.65	1.50	.38	1.10	.99	.08	.22	.19	.18	.19
346	Subsoil	do	8.78	13.39	44.04	14.78	13.97	1.48	.41	1.49	1.41	.07	.26	.21	.12	.18
25	Kohaluu	do	7.59	18.34	29.70	20.40	22.84	.....	.02	.15	.70	.16	.23	.12	.29	.32
	Heeia:															
319	Soil	do	11.22	17.69	26.40	23.95	16.52	3.10	.02	.66	.62	.27	.03	.51	.31	.31
320	Subsoil	do	19.49	13.85	23.82	22.67	15.89	2.80	.04	.58	.49	.23	.12	.44	.28	.21
	Near wireless station, Heeia:															
304	Soil	do	10.34	13.80	32.59	17.95	21.04	2.90	.05	.90	.68	.25	.30	.49	.10	.24
305	Subsoil	do	10.26	13.92	32.73	17.87	21.90	2.50	.04	.87	.80	.25	.19	.52	.12	.24
302	Soil	Red	11.74	20.95	16.59	27.52	15.77	5.00	.28	.39	1.16	.28	.08	.90	.17	.53
303	Subsoil	Brown	9.49	14.86	30.47	20.26	21.23	2.60	.08	.53	.62	.23	.25	.49	.08	.20
131	Lilipuna	Red	16.94	15.82	35.30	14.88	15.16	.....	.45	.29	.51	.51	.35	.38	.31	.31
508	Do	Brown	4.96	14.02	42.81	14.96	19.71	2.60	.17	.20	.58	.40	.28	.25	.34	.02
509	Do	Red	3.41	14.02	46.33	12.80	19.38	2.60	.26	.20	.60	.40	.38	.30	.34	.02

TABLE I.—*Chemical composition of Hawaiian soils*—Continued.

Soil No.	Location.	Color.	Water (H_2O).	Volatile matter.	Insoluble residue.	Ferric oxid (Fe_2O_3).	Alumina (Al_2O_3).	Titanium dioxid (TiO_2).	Manganese oxid (Mn_3O_4).	Lime (CaO).	Magnesia (MgO).	Potash (K_2O).	Soda (Na_2O).	Phosphoric acid (P_2O_5).	Sulphur trioxid (SO_3).	Nitrogen (N).
	OAHU—continued.															
	Koolaupoko district—Continued.															
194	Kaneohe, Hawaiian Pineapple Co.	Red	*Per ct.* 15.03	*Per ct.* 16.52	*Per cent.* 20.39	*Per cent.* 29.59	*Per cent.* 15.05	*Per cent.*	*Per cent.* 0.30	*Per cent.* 0.18	*Per cent.* 0.80	*Per cent.* 0.94	*Per cent.* 0.70	*Per cent.* 0.54	*Per cent.* 0.28	*Per ct.* 0.29
195	Do	do	11.42	15.44	31.24	22.12	16.70	.....	.14	.32	.60	.56	.70	.72	.24	.30
196	Do	Black	15.02	14.27	25.80	25.52	15.81	.....	.24	.68	.76	.52	.42	.71	.26	.28
197	Do	Red	9.83	15.69	37.88	18.48	15.34	.....	.03	.26	.88	.54	.74	.45	.30	.32
198	Do	Black	12.21	14.91	27.17	26.62	16.65	.....	.21	.22	.66	.64	.66	.41	.28	.28
	Kaneohe, near Pali:															
300	Soil	Brown	7.50	12.61	27.65	34.92	10.95	3.70	.10	.48	1.49	.24	.19	.90	.13	.35
301	Subsoil	do	9.26	10.35	26.67	35.08	13.22	3.30	.09	.28	1.10	.33	.45	.76	.08	.21
	Kaneohe, Koelings:															
306	Soil	Black	8.12	15.40	32.67	16.47	23.28	3.10	.03	.78	.66	.31	.18	.52	.10	.32
307	Subsoil	Red	10.93	17.05	16.63	26.01	22.99	4.00	.02	.44	.91	.23	.18	.98	.14	.28
	Kaneohe, Mauka road:															
308	Soil	do	9.62	18.32	20.35	20.04	26.09	2.70	.04	.64	1.01	.16	.40	.87	.25	.31
309	Subsoil	do	13.08	16.12	21.06	20.96	22.35	2.80	.6	1.11	1.50	.08	.14	.90	.38	.29
310	Soil	do	14.65	16.44	20.59	23.90	20.36	3.00	.03	.41	.37	.16	.56	.28	.18	.22
311	Subsoil	do	18.64	15.46	20.72	21.20	19.43	3.50	.02	.22	.43	.11	.31	.32	.21	.17
312	Soil	Brown	11.49	18.35	25.01	17.87	23.45	2.90	.32	.34	.45	.08	.24	.38	.22	.27
313	Do	Red	8.69	11.17	21.28	38.25	11.98	4.80	.18	.74	1.64	.31	.69	.76	.29	.31
314	Subsoil	do	8.74	10.55	24.66	35.94	12.04	5.00	.04	.58	1.51	.23	.49	.66	.27	.25
315	Soil	do	8.76	17.34	25.38	19.02	23.17	5.00	.23	.43	.54	.11	.31	.53	.24	.26
316	Subsoil	do	6.69	16.79	30.75	19.57	21.86	3.40	.06	.35	.47	.18	.06	.54	.25	.21
317	Soil	Black	11.95	16.42	28.90	20.54	17.30	3.50	.06	.57	.51	.23	.06	.28	.31	.30
318	Subsoil	do	13.92	15.49	27.77	18.84	18.22	4.00	.05	.46	.51	.24	.06	.42	.24	.29
	Kaneohe:															
343	Soil	do	9.38	12.58	45.47	10.21	18.39	2.04	.46	1.11	.79	.09	.33	.18	.03	.18
344	Subsoil	do	11.35	10.87	45.21	9.29	18.73	2.10	.46	1.44	.65	.13	.34	.20	.03	.15
	Kailua coconut plantation:															
335	Soil	White	38.18		6.71	.65	.23	.00	.00	50.05	2.67	.20	.60	.27	.44	.16
336	Subsoil	do	40.45		3.86	.36	.38	.00	.00	50.92	2.69	.20	.60	.08	.46	.06
	Kailua:															
337	Soil	Brown	8.67	17.00	37.02	17.32	13.64	2.22	.08	.69	.75	.24	.41	.69	.24	.40
338	Subsoil	do	10.74	16.46	38.12	17.62	12.97	1.90	.24	.53	.44	.14	.41	.61	.23	.38
339	Soil	do	8.90	19.15	33.75	22.69	11.60	2.66	.07	.39	.24	.13	.40	.26	.18	.37
340	Subsoil	do	10.86	16.41	34.14	23.29	11.08	2.50	.10	.42	.28	.05	.33	.20	.18	.27

510	Soil	...do....	7.57	15.74	41.86	12.00	18.25	3.20	.18	.41	.98	.26	.60	.24	.50	.....
511	Subsoil	...do....	9.04	14.26	40.93	11.12	17.33	4.00	.14	.47	1.02	.18	.62	.25	.54	.....
512	Soil	...do....	9.04	14.49	41.23	11.64	19.03	3.40	.12	.46	1.06	.18	.44	.23	.50	.....
513	Subsoil	...do....	9.69	16.81	39.49	10.28	19.07	3.20	.06	.48	1.04	.20	.54	.23	.46	.....
	Kaelepulu:															
491	Soil	Red.....	6.74	11.89	26.04	28.12	9.70	2.40	.28	1.46	9.94	.74	.34	1.72	.58	.16
492	Subsoil	...do....	10.71	7.26	35.04	15.12	12.70	3.80	.22	3.48	8.90	1.50	.56	.50	.58	.02
223	Soil	Gray....	1.16	41.85	3.20	.93	.00	.....	.96	49.46	1.90	.26	.39	.39	.82	.19
	Kawailoa:															
224	Soil	Red.....	6.01	26.39	23.38	16.88	9.98	.....	.00	13.96	1.56	.50	.04	1.32	.64	.60
225	Do	Brown..	7.72	8.37	55.89	12.98	11.65	.....	.05	1.27	1.83	.34	.13	.12	.25	.12
226	Do	Red.....	6.44	11.22	45.90	19.84	14.06	.....	.11	1.05	1.16	.42	.15	.05	.20	.15
227	Do	White...	.36	40.66	2.60	.21	.00	.....	.00	51.74	2.90	.31	.46	.21	.55	.04
228	Subsoil	Blue....	.42	40.90	3.08	.29	.00	.....	.00	50.78	2.91	.32	.45	.24	.61	.03
	Maunawili:															
341	Soil	Brown..	9.65	16.43	17.69	27.00	25.50	2.21	.04	.40	.77	.27	.26	.69	.29	.15
342	Subsoil	...do....	10.59	17.37	16.54	28.16	22.16	2.90	.14	.28	1.06	.33	.65	.84	.33	.31

TABLE II.—*Humus, humus ash, and total nitrogen in Hawaiian soils.*

Soil No.	Location.	Humus.	Humus ash.	Total nitrogen.
	HAWAII.			
	Puuanahulu:	*Per ct.*	*Per ct.*	*Per ct.*
326	1,300-foot level.	6.49	1.19	0.33
327	1,400-foot level.	3.08	1.44	.26
328	1,500-foot level.	7.01	1.71	.27
	Parker ranch, Waimea:			
474	Soil	7.96	3.65	.65
475	Subsoil	6.50	2.90	.60
468	Parker ranch, Makahalau	9.64	3.32	.64
74	Parker ranch, Waikii	5.54	1.33	.41
75	Do	4.06	1.62	.23
76	Do	3.51	1.46	.18
448	Hilo	3.10	1.24	.49
428	Glenwood	12.32	3.32	.74
221	Do	11.30	2.20	.55
	Pahala, 3,000-foot level:			
497	Soil	6.96	.....	.36
498	Subsoil	5.74	2.35	.24
	Honaunau:			
422	460-foot level	16.36	3.90	1.68
423	Subsoil	10.32	4.15	.81
418	760-foot level	3.98	2.40	.41
419	Subsoil	3.22	2.82	.31
	Kiilae:			
437	2,050-foot level.	25.52	4.20	2.13
438	Subsoil	14.76	6.52	.61
439	2,700-foot level.	14.56	2.58	.74
	KAUAI.			
	Makaweli:			
493	Soil	3.35	.90	.28
494	Subsoil	2.38	1.96	.09
	Kekaha:			
495	Soil	2.80	1.90	.01
496	Subsoil	1.65	1.10	.10
117	Hanapepe	4.60	2.44	.23
	Kauai Fruit & Land Co.:			
429	Soil	4.28	1.29	.30
430	Subsoil	2.54	1.06	.16
207	Homestead	2.89	.71	.36
	Kapaa:			
426	Soil	4.41	1.36	.29
427	Subsoil	3.71	1.36	.16
211	Kilauea	4.71	1.04	.31
463	Hanalei	2.55	1.39	.16
467	Do	2.56	1.42	.15
	MAUI.			
60	Haiku	3.61	.....	.27
544	Do	4.27	.98	.26
545	Do	3.92	1.10	.32
551	Do	4.16	1.31	.28
552	Do	4.25	1.00	.27
557	Do	4.56	1.06	.34
558	Do	5.21	2.11	.30
69	Nahiku	19.13	6.33	1.32
	Kaupo, Omsted place:			
525	Soil	6.70	1.92	.....
526	Subsoil	4.29	1.81	.....
61	Kula, Dowdle field	6.72	1.03	.52
	Ulupalakua ranch:			
377	Soil	2.34	1.04	.31
378	Subsoil	2.76	1.10	.27
	Kamaole Church:			
381	Soil	2.92	1.02	.49
382	Subsoil	1.25	.65	.38

Soil No.	Location.	Humus.	Humus ash.	Total nitrogen.
	MAUI—continued.			
	Honolua:	*Per ct.*	*Per ct.*	*Per ct.*
363	650-foot level	3.90	3.10	.29
364	Subsoil	1.43	.97	.14
365	850-foot level	3.88	1.25	.36
366	Subsoil	2.42	1.25	.15
	MOLOKAI.			
	Naiwa district.			
	1,500-foot level:			
349	Soil	3.37	1.13	.24
350	Subsoil	4.64	2.86	.19
	860-foot level:			
353	Soil	1.65	.71	.18
354	Subsoil	1.28	.86	.13
	380-foot level:			
357	Soil	.94	.46	.08
358	Subsoil	.98	.68	.08
	30-foot level:			
359	Soil	2.20	.84	.25
360	Subsoil	3.76	1.79	.19
	OAHU.			
	Waikiki:			
71	Soil	2.00	.....	.16
292	Do	1.49	1.27	.14
293	Subsoil	1.76	1.19	.13
	Experiment station:			
288	Soil	3.06	1.48	.21
289	Subsoil	2.71	1.71	.15
290	Soil	1.66	.36	.19
291	Subsoil	1.55	2.25	.12
	Hawaiian Pineapple Co., Wahiawa:			
7	Soil	3.03	1.60	.32
9	Do	3.18	.54	.18
97	Do	2.64	.54	.23
98	Do	2.81	.75	.23
99	Do	3.84	.57	.24
101	Do	3.61	.78	.22
102	Do	3.37	.70	.25
103	Do	4.74	1.12	.21
104	Do	3.22	.76	.19
100	Subsoil	3.48	.64	.17
19	Thomas Pineapple Co., Wahiawa.	2.98	1.45	.22
282	Leilehua	2.77	1.04	.40
283	Do	1.78	.79	.26
284	Do	2.72	.70	.32
285	Do	2.03	.63	.34
286	Do	3.15	.94	.44
287	Do	3.64	1.38	.38
	Kaneohe:			
300	Soil	5.93	1.46	.35
301	Subsoil	3.49	1.41	.21
	Heeia:			
302	Soil	9.65	2.31	.53
303	Subsoil	3.10	1.66	.20
304	Soil	2.74	.61	.24
305	Subsoil	2.88	.66	.24
	Kaneohe:			
306	Soil	3.86	1.36	.32
307	Subsoil	4.99	1.42	.28
308	Soil	4.06	1.03	.31
309	Subsoil	3.14	.83	.29
310	Soil	4.99	1.26	.22
311	Subsoil	4.18	1.00	.17
	Maunawili:			
341	Soil	3.44	1.38	.15
342	Subsoil	4.13	1.25	.31

TABLE III.—*Mechanical composition of Hawaiian soils.*

Soil No.	Location.	Volatile matter.	Fine gravel.	Coarse sand.	Fine sand.	Silt.	Fine silt.	Clay.
	HAWAII.							
	Kohala district.							
	Puuanahulu:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
326	1,300-foot level	17.15	0.22	0.58	22.48	19.28	28.64	13.54
327	1,400-foot level	18.31	.24	.65	30.46	17.58	20.73	13.26
328	1,500-foot level	17.41	.34	.73	22.86	14.81	25.15	19.94
74	Parker ranch, Waikii	25.83	1.64		38.03	16.22	19.99	2.05
75	Do	21.75	.03	3.48	29.50	18.65	20.75	4.48
76	Do	19.45	.02	2.14	26.70	22.90	24.45	3.55
573	Do	23.30	1.71		36.20	21.82	13.60	3.75
	Hilo district.							
448	Hilo	32.95	1.94	8.60	16.31	13.45	20.00	6.85
	Olaa district.							
428	Glenwood	29.85	13.81	32.82	15.83	5.38	1.76	.69
	Kona district.							
111	Keahui	22.65	.00	14.42	32.15	12.65	14.17	5.38
112	Do	32.70	.07	3.22	17.60	15.70	24.50	6.58
113	Do	33.60	.12	2.49	15.23	13.62	25.80	7.10
	Hanauhau:							
422	460-foot level	43.50	1.66	1.87	26.29	16.03	10.33	1.07
423	Subsoil	26.97	1.97	2.98	36.75	21.63	9.19	.99
420	510-foot level	22.93	2.17	2.26	16.62	17.46	31.88	7.16
421	Subsoil	19.12	.49	1.29	16.31	14.07	35.48	14.03
424	680-foot level	20.30	3.18	3.99	22.15	21.63	23.61	3.98
425	Subsoil	16.87	3.95	5.15	22.02	19.58	25.76	6.29
418	760-foot level	17.95	3.10	3.04	20.72	21.04	27.65	6.67
419	Subsoil	13.42	5.25	5.10	19.43	19.19	28.52	9.09
	KAUAI.							
	Kona district.							
116	Hanapepe	18.75	.02	1.57	5.48	6.49	33.40	35.50
117	Do	19.90	.10	3.11	7.58	7.22	36.50	27.40
118	Do	15.60	1.23		11.78	11.65	24.20	35.80
119	Do	13.74	.34		5.72	4.65	33.20	43.70
120	Do	17.85	1.45		4.17	4.43	34.20	39.10
	Koloa:							
373	Soil	21.41	.10	.40	9.66	12.78	29.01	27.24
374	Subsoil	16.42	.06	.12	11.88	9.04	22.28	41.09
375	Soil	25.28	.24	.42	18.35	10.31	32.45	15.04
376	Subsoil	19.21	.12	.45	26.89	13.37	20.69	20.92
	MAUI.							
	Hamakuapoko district.							
61	Haiku	25.16	.12	7.20	40.90	9.85	15.01	2.93
	Koolau district.							
69	Nahiku	44.60	5.94	26.72	8.65	4.07	5.09	5.78
	Kula district.							
	Alexander field:							
105	Soil	11.59	0.98		20.40	9.53	35.80	22.55
109	Subsoil	14.80	0.53		5.71	5.62	11.55	64.10
106	Soil	12.00	1.12		20.40	9.26	36.30	21.85
108	Subsoil	15.55	0.96		13.58	6.25	13.35	51.26
	Dowdle field:							
107	Soil	10.57	1.21		21.21	10.63	39.88	15.87
110	Subsoil	14.92	0.92		5.18	7.77	17.20	54.30
	Kaanapali district.							
	Honolua:							
361	450-foot level	16.22	.64	.94	39.51	16.02	9.73	17.36
362	Subsoil	13.09	.08	.12	14.47	10.84	26.43	35.57
363	650-foot level	16.11	.43	.68	19.79	17.59	26.51	19.39
364	Subsoil	13.32	.05	.24	13.09	11.63	29.11	33.32
365	850-foot level	16.46	.01	1.90	11.64	20.89	37.95	13.89
366	Subsoil	17.22	.07	.15	4.02	7.11	18.64	54.11

TABLE III.—*Mechanical composition of Hawaiian soils*—Continued.

Soil No.	Location.	Volatile matter.	Fine gravel.	Coarse sand.	Fine sand.	Silt.	Fine silt.	Clay.
	MOLOKAI.							
	Naiwa district.							
	1,500-foot level:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
349	Soil	10.71	0.46	1.00	22.05	12.34	45.95	8.91
350	Subsoil	16.38	.03	.24	9.80	8.99	27.20	39.70
	1,050-foot level:							
351	Soil	9.06	.08	.36	13.89	20.32	45.99	10.98
352	Subsoil	13.18	.01	.16	11.41	9.09	24.99	43.23
	860-foot level:							
353	Soil	15.24	.03	.41	35.86	18.59	18.78	12.09
354	Subsoil	13.54	.05	.54	30.67	20.49	19.05	16.10
	600-foot level:							
355	Soil	13.05	.01	.73	36.15	14.89	19.47	15.85
356	Subsoil	12.48	.00	.86	40.41	15.35	18.06	14.22
	380-foot level:							
357	Soil	12.95	.03	.23	39.84	17.72	14.40	14.97
358	Subsoil	12.98	.00	.15	40.54	14.96	13.67	17.75
	30-foot level:							
359	Soil	15.39	.25	.55	44.65	21.98	9.91	7.45
360	Subsoil	17.82	.00	.13	48.13	23.73	6.59	3.96
	OAHU.							
	Kona district.							
	Waikiki:							
292	Soil	8.71	20.91	18.75	22.04	8.69	12.41	7.23
293	Subsoil	10.77	18.61	18.30	22.74	8.10	13.48	9.52
	Experiment station:							
288	Soil	14.42	.85	7.92	16.19	10.94	25.31	24.89
289	Subsoil	13.82	.56	6.16	8.89	6.96	24.07	40.35
290	Soil	16.22	.14	.58	7.77	9.33	18.14	48.35
291	Subsoil	14.37	.00	.39	7.40	7.28	12.13	59.35
	Kalihi:							
332	Soil	14.37	1.15	1.61	18.34	16.28	23.88	25.37
333	Subsoil	14.05	1.02	1.28	20.63	17.88	22.11	24.06
334	Soil	15.23	.62	1.63	15.33	15.77	21.73	31.61
	Waipio district.							
114	Hawaiian Pineapple Co.	16.60	.04	1.62	8.94	9.08	31.35	32.20
	Wahiawa district.							
	Hawaiian Pineapple Co:							
7	Soil	13.14	.00	.77	3.64	8.85	34.54	36.28
9	Do	16.77	.87	8.20	22.44	13.94	23.13	13.11
97	Do	14.32	.09	.43	1.62	3.31	27.19	52.30
98	Do	13.65	.12	.43	2.11	3.06	26.32	55.05
99	Do	15.80	.73	.86	2.35	9.28	32.69	38.60
101	Do	13.06	.14	.50	1.33	6.23	28.88	47.45
102	Do	14.67	.29	.91	1.12	7.38	18.87	57.80
103	Do	17.58	.05	.26	.81	5.60	22.70	56.72
104	Do	16.17	.09	.42	2.36	6.44	29.07	44.54
100	Subsoil	15.55	.41	1.65	1.65	6.72	18.45	57.80
530	Soil	14.41	0.50		5.97	10.74	39.40	28.95
19	Thomas Pineapple Co.	13.35	0.60		2.31	6.79	38.42	37.58
15	Hawaiian Preserving Co.	16.66	2.54	6.28	21.17	14.57	21.90	15.50
516	Do	19.70	3.79	5.90	33.10	11.50	17.56	8.42
574	Do	15.13	1.24	.39	8.71	10.10	26.90	37.70
542	Kunia	19.35	0.88		33.95	14.55	19.34	11.95
282	Leilehua	20.34	.69	2.31	23.44	12.84	23.69	18.45
283	Do	18.88	.80	2.86	23.79	11.75	20.95	22.59
284	Do	21.20	.69	2.41	28.11	11.26	19.86	19.51
285	Do	19.91	.95	2.39	25.62	10.69	22.71	19.37
286	Do	21.11	.34	1.76	24.89	13.13	23.65	16.71
287	Do	20.48	.91	1.80	27.47	11.13	22.96	17.90
	Waialua district.							
331	Helemano	20.43	.01	1.65	45.17	12.86	9.82	11.31
164	Opaeula	3.61	0.17		3.79	19.50	51.70	21.10
115	Do	12.88	0.47		3.72	6.03	45.40	31.80
	Pupuukea:							
49	Soil	14.54	.02	.42	11.65	11.41	46.30	16.77
50	Subsoil	14.15	.04	.23	3.88	6.67	28.43	48.57
51	Soil	16.39	1.98	3.67	19.57	9.16	32.09	19.13
52	Subsoil	13.54	2.16	6.71	11.22	7.43	23.75	36.69

TABLE III.—*Mechanical composition of Hawaiian soils*—Continued.

Soil No.	Location.	Volatile matter.	Fine gravel.	Coarse sand.	Fine sand.	Silt.	Fine silt.	Clay.
	OAHU—Continued.							
	Koolauloa district.							
	Koluanui:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
347	Soil	36.14	0.41	0.83	21.49	27.45	7.61	6.38
348	Subsoil	49.24	.22	.64	11.29	15.27	20.07	6.19
	Koolaupoko district.							
	Waiahole:							
345	Soil	15.04	.15	3.09	25.94	20.97	15.96	19.84
346	Subsoil	15.31	.46	3.59	34.44	19.30	10.96	14.29
319	Heeia	20.31	.11	.54	20.98	18.07	25.31	16.42
	Kaneohe:							
300	Soil	13.94	.75	.59	24.11	14.47	35.03	11.05
301	Subsoil	11.71	.23	.35	31.08	19.13	21.91	15.59
	Wireless Station, Heeia:							
302	Soil	23.71	.23	.48	15.56	17.66	31.42	11.44
303	Subsoil	16.43	.22	.23	5.93	9.42	25.72	42.78
304	Soil	16.14	.17	.42	16.76	16.61	25.47	23.53
305	Subsoil	16.13	.23	.32	12.78	15.51	27.79	26.78
	Koeling's, Kaneohe:							
306	Soil	17.34	.22	.35	10.50	13.03	37.03	22.06
307	Subsoil	19.44	.17	.53	26.64	16.17	28.53	8.76
	Kaneohe:							
308	Soil	19.12	.96	1.10	17.57	14.00	35.86	10.72
309	Subsoil	18.21	.74	.94	17.66	15.97	36.36	10.90
310	Soil	18.53	.19	.54	13.40	19.08	29.24	20.07
311	Subsoil	17.81	.26	.62	10.41	15.09	21.65	32.45
312	Soil	22.42	.21	.96	25.76	13.54	25.19	14.74
313	Do	13.64	.63	1.46	20.90	45.63	11.38	8.34
314	Subsoil	11.95	.35	1.00	24.68	26.08	27.35	7.55
315	Soil	20.69	.32	1.35	23.80	15.21	21.91	19.25
316	Subsoil	17.77	.33	.87	23.79	20.87	17.34	20.04
317	Soil	19.08	.13	.56	12.62	16.82	26.53	25.83
318	Subsoil	19.30	.09	.75	16.14	22.17	24.82	18.17
343	Soil	15.44	.05	.19	16.03	30.79	14.64	20.16
344	Subsoil	13.20	.22	.11	15.29	28.94	20.67	21.73
	Kailua:							
337	Soil	18.72	.35	.69	18.78	13.57	22.92	25.70
338	Subsoil	19.54	.33	.86	18.60	15.97	21.97	23.19
339	Soil	21.17	.13	.22	18.13	20.42	22.37	19.19
340	Subsoil	19.41	.06	.31	16.75	19.27	23.42	22.98
	Maunawili:							
341	Soil	19.39	.27	.96	32.29	20.92	15.64	12.26
342	Subsoil	20.61	.58	1.31	17.90	16.18	34.39	11.37

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